

KINEMATIC GLOBAL POSITIONING SYSTEM SURVEYS IN SOUTHERN ARIZONA

Donald R. Pool (U.S. Geological Survey, Tucson, Arizona)

Kinematic Global Positioning System (GPS) surveys have been used in southern Arizona to quickly obtain accurate altitudes for more than 1,000 well heads, gravity stations, and bench marks and to survey large areas for subsidence distributions. Altitudes are referenced to the National Geodetic Vertical Datum of 1929 (NGVD of 1929). Prior to GPS, altitudes typically were estimated with questionable accuracies from topographic maps because traditional surveys were costly and time consuming. In contrast, kinematic GPS surveys yield altitudes that generally are accurate to 5 cm as long as vector lengths are within about 15 km (see Ikehara #1 and #2 abstracts where for static GPS surveys 1–2 cm level accuracies are expected and achieved).

The survey measures vectors between a static antenna and an antenna that roves among survey points using signals broadcast from military GPS satellites. The static receiver is placed at a bench mark or triangulation station with a known vertical or horizontal position. Vectors to each survey station and geographic position of each station are determined during postprocessing of field data.

Kinematic GPS surveys sacrifice the centimeter-level accuracy of static GPS surveys for greater speed and quantity of positions. Continuous monitoring of a single frequency signal, 19-cm wavelength, from four or more satellites is required. Good satellite geometry is required, which means that the satellites should be spaced across a large area of the sky. Signals from satellites below 13° above the horizon are not used because of excessive noise caused by the atmosphere. In late 1992, 24 satellites are available and surveying can be carried out nearly 24 hours each day.

Surveys must begin with a 10-minute initialization procedure to establish signal bias, which is the number of integer wavelengths between each satellite and the antennas. Signal biases are estimated using baseline or antenna-swap initialization techniques. Baseline initialization requires the remeasurement of a previously measured vector. Antenna-swap initialization requires exchanging the static and roving antennas between two points separated by 5 to 10 m.

The survey consists of roving by vehicle or walking with one antenna and collecting data for 2 to 5 minutes at each station. Some obstructions cannot be avoided while roving, resulting in an interrupted signal. When the signal from a satellite that is essential for good geometry is interrupted, bias on that signal must be reestablished. Often, five or more satellites are monitored and therefore the loss of signal from one satellite does not require reinitialization. When loss of signal results in poor satellite geometry, the signal must be reinitialized by reoccupying a previously measured vector. This vector can be one measured during the same survey, including initialization baseline or antenna-swap point, or one measured during a separate survey.

The typical kinematic survey is impractical in areas with many large trees, developed areas with buildings two or more stories tall, and narrow canyons. Two GPS alternatives, pseudo-static and rapid-static surveys, are available for these areas. The pseudo-static method requires two occupations of 10 minutes for each station but does not require continuous monitoring of satellite signals. The rapid-static method requires a single measurement lasting 20 minutes but is a dual-frequency method that uses more expensive hardware and software.

The typical survey includes 20 or more vector measurements over a 3- to 4-hour period with some redundancy for purposes of error checking (fig. 1). Redundancy is accomplished through inclusion of

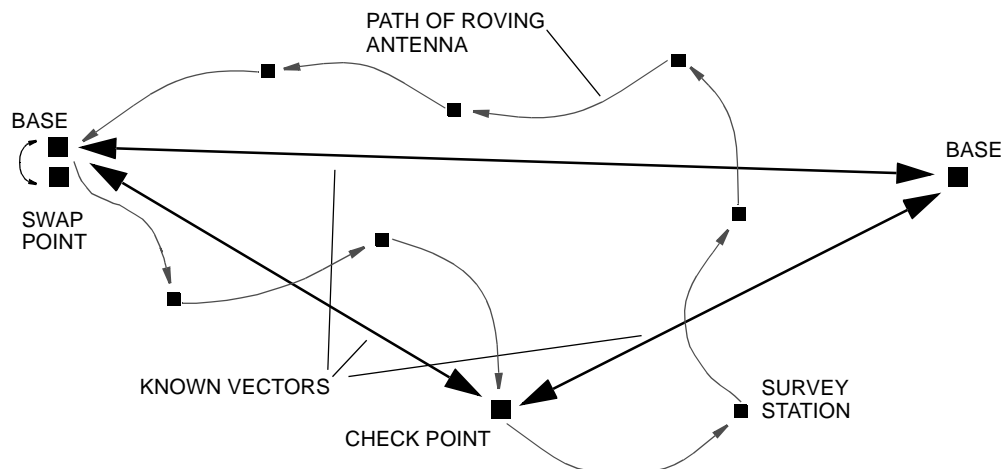


Figure 1. Typical kinematic Global Positioning System survey.

previously measured vectors, repeat measurements, and two base stations. Ideally, one previously measured vector should be remeasured after biases are reestablished on an important satellite signal. Use of two base stations is advantageous because redundancy of positions are provided for each station, power failures or other problems at one base do not cause a total loss of the survey, and poor initializations or mismeasured antenna heights at base stations will be evident from vector-closure errors (see Ikehara #2 abstract for discussion of errors in GPS surveys).

Field data are postprocessed using software from manufacturers of the GPS receivers or the National Geodetic Survey. Basic information necessary for processing include antenna heights and type of initialization. Processing of large surveys can take as much as 45 minutes of computation time. Survey quality can be quickly assessed through inspection of the resulting vectors and comparing repeated measurements. Data can be reprocessed if some of the vectors are suspect or if biases were not accurately estimated. A final fix to recover from unreliable vectors is to remeasure a key vector and then reprocess the data set using the new vector as an initialization baseline.

Processed vectors are loaded into a network-adjustment program and a least-squares adjustment is applied, resulting in the compilation of closure errors and standard errors for each surveyed point. Coordinates of each station in several ellipsoidal coordinate systems can be determined from the known horizontal and vertical positions of base stations.

The final stage of processing is to determine the altitude of each station relative to NGVD of 1929 using the program GEOID90 (Milbert, 1991b). Comparisons of NGVD of 1929 altitudes determined by kinematic methods with the altitude of first-order benchmarks indicate an accuracy better than 10 cm and often better than 5 cm when vector lengths are kept to about 15 km or less.

Kinematic GPS surveys have been a useful tool that has improved the accuracy of altitude-sensitive data and broadened the scope of projects that can be pursued. Accurate well-head altitudes can be measured rapidly and provide more accurate estimates of ground-water gradients. Accurate altitudes increase the accuracy and expand the use of gravity surveys to the detection of small amplitude anomalies that are common in ground-water hydrology. Areas of potential subsidence that have not been surveyed because of cost and time constraints can be easily surveyed. More applications of kinematic surveys are expected in the future.